Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SSS02-01 会場:201B 時間:5 月 21 日 09:00-09:15

Short-term earthquake forecasting experiment before and during the L'Aquila seismic sequence of April 2009
Short-term earthquake forecasting experiment before and during the L'Aquila seismic sequence of April 2009

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In this study, we compare the forecasting performance of several statistical models, which are used for describing the occurrence process of earthquakes, in forecasting the short-term earthquake probabilities during the occurrence of the L'Aquila earthquake sequence in central Italy, 2009. These models include the Proximity to Past Earthquake (PPE) model and two versions of the Epidemic Type Aftershock Sequence (ETAS) model. We used the information gains corresponding to the Poisson and binomial scores to evaluate the performance of these models. It is shown that both ETAS models work better than the PPE model. However, when comparing between the two types of the ETAS models, the one with the same fixed exponent coefficient ¥alpha=2.3 for both the productivity function and the scaling factor in the spatial response function (Model I), performs better in forecasting the active aftershock sequence, than the other model with different exponent coefficients (Model II) even though Model I is a subclass of Model II; Model II performs only better when a lower magnitude threshold of 2.0 and the binomial score are used. The reason is found to be: the catalog does has an event of similar magnitude as the L'aquila mainshock in the training period, and ¥alpha-value is under estimated and thus the forecasted seismicity is underestimated when the productivity function is extrapolated to high magnitudes. These results suggest that the training catalog used for estimating the model parameters should include earthquakes of similar magnitudes as the mainshock when forecasting seismicity in the duration of an aftershock sequences.

キーワード: 地震予測, 確率予測, ETAS モデル, 確率増益, 2009 年 L'quila 地震
Keywords: earthquake forecast, probability forecast, ETAS model, information gain, 2009 L'aquila earthquake

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Forecasting Moderate Seismicity by Using the Moment Ratio Method
Forecasting Moderate Seismicity by Using the Moment Ratio Method

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Abstract. Recently, we introduced a new alarm-based forecasting model for earthquakes, called moment ratio (MR) model. In this model, the ratio of the mean inter-event time over the variance is used as a precursory alarm function to forecast future earthquakes in a given region. In a former study, this model was successfully tested in forecasting large earthquakes with magnitude M >= 7, occurred in Japan. As a first step towards testing the applicability of our model in forecasting earthquakes in moderate seismicity areas as Northern Algeria, the MR model is tested on target earthquakes with magnitude M >= 5. For this purpose, a composite catalog covering all Japan within the period 679-2011 is used. This catalog was compiled using the Japan Meteorological Agency (JMA) catalog for the period 1923-2011 and the Utsu historical seismicity records for the period 679-1922. Time periods used in training and testing are selected by taking into account the completeness of the magnitude. Molchan error diagrams are used to evaluate the forecasting performance of the MR method in a series of retrospective tests applied at short, intermediate and long-term. Then, MR forecasting maps are obtained based on minimizing miss and alarm rates. The limitations of the MR model are discussed focusing on cases of poor catalog data with epicenter location errors. The applicability of the Collaboratory for the Study of Earthquake Predictability CSEP prospective tests to the MR method is discussed by tuning different free parameters of the model. Results show that the minimal inter-event time sample size used to calculate the moment ratio together with the size of inter-event time sampling area shape the study region, and play important role in the calibration of our model to CSEP ’rules of game’. Finally, we discuss the impact of the MR forecasts on seismic hazard assessment in a given region.

キーワード: Earthquake forecasting, Inter-event times, Alarm function, Molchan diagram
Keywords: Earthquake forecasting, Inter-event times, Alarm function, Molchan diagram

SSS02-03 会場:201B 時間:5 月 21 日 09:30-09:45

自然地震発生直前の微小クラックによる破壊核形成期の同定（２）
Identification of the Nucleation Stage of Natural Earthquakes by Monitoring Microcracks

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はじめに

２０１２年の合同大会では、東北日本太平洋沖地震に伴って検出されたパルス状の変動の解析の結果、　電磁気な手法によって地震発生前後のマイクロクラックが検出できる可能性があること、　ＤＣ帯では火山活動、群発地震に伴って発生することがわかっていたＵＬＦ／ＶＬＦ帯のパルス状の変動（間歇泉型変動）に注目していたが、それと殆ど同じ変動が検出された（これをＡ型という、図１－a）こと、　ＡＣ帯では継続時間１０ｍｓ以下の単パルス状の変動で、地震の前に急激に増大するものがあることを報告した。ここでは、波形の詳細な解析を結果明らかとなった事柄を報告する。

２．ＡＣ帯のパルス状の変動は、周波数帯がＳＬＦ帯（約４００ Hz）のもの（Ｂ型）と、ＶＬＦ帯（約４ｋＨｚ）のもの（Ｃ型、図１ーe）にわけられる。Ｂ型は、Ａ型の変形（Ｂ－１、図１－ｂ）と波束型（Ｂ－２, 図１－ｃ)、およびそれらの混合型（Ｂ－３、図１－ｄ）に分類できる。

Ｂ型は地震の直前にのみ発生し、３月６日から増加し、３月９日の最大、１０日に少なくなり増加に転じ１１日の地震を迎えた。積算パルス数の時間変化 N(t) は、破壊時 tf を 10.8 日とする冪関数 (tf ?t)-n で記述され地震発生の 11.6 日とよい対応を示す。指数 n はほぼ３で、前震の場合の 1.7（Varnes,1989; Maeda,1999）岩石実験の場合の 0.5（Yoshida,1994）とは、異なる。DC 帯の間歇泉型は、地震前に一例ある以外はすべて地震後に発生した。また、高周波数のＣ型は、地震後にのみ検出された。

観測されたＢ帯の変動は、岩石破壊実験でのＡＥ波形・時空間分布とかなり類似しており、地震直前の破壊核形成期のマイクロクラック発生によるものと考えることができる。電界強度は GUV が数μ V/m、UUV が 0.1 μ V/m と小さく、高感度かつ環境ノイズにロバストな計測方向により検出される。現在のところボアホール計測が唯一の計測方法である。

３．考察

１）多段間欠泉型は開口性のクラック（第　型）に、波束型はシェア型（第　、第　型）クラックに、混合型は第　型と第　、　型との連結により発生していることが、岩石破壊実験の結果をもとに推測される。２）マイクロクラックと電磁界現象の相互作用は、流動電位効果によるものと推定される。

３）地震後のＣ型は余効段階のおけるジョイントのかみ合い、Ａ型はジョイントへの大量の間隙水の出入によるものと、推定される。

４）電界変動計測による大きな検知距離は、クラック発生に伴う弾性波動が間隙水の流動電位効果により電磁波に変換され、媒質の境界にトラップされて弾性波に比べて何桁も小さな減衰率を有するためと考えられる。

４．結論

自然地震の破壊核形成がマイクロクラックをモニタすることで判定できること、地震の直前予測手法の発展に新たな展開が期待されることを示した。

謝辞：

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キーワード: 地震直前予測, 破壊核形成, マイクロクラック, 電磁気現象, 間隙水流動
Keywords: earthquake precursor, nucleation stage, microcrack, electric phenomena, confined water

SSS02-03 会場:201B 時間:5 月 21 日 09:30-09:45

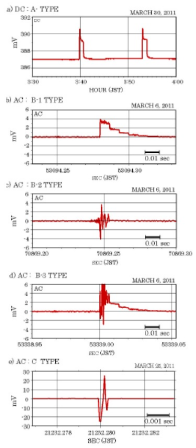

Figure 1

a) Waveform of the pulse-like particular signals in the DC band (type A). Type A has a duration of several tens of seconds to several tens of minutes, and a height of about 2–3 mV. The form was first identified by the temporally rapid recording at the time of volcanic eruption activities in 1990 at Izu-Oshima (Fujinawa *et al*, 2001). Afterward, we detected similar signals at almost cases of nearby volcanic eruption and seismic swarms (11).

(b) Type B-1 waveform of the pulse-like signals in the AC band. The form is very similar to type A except that it is of smaller duration (several tens of ms) and shows several steps in the process of relaxation.

(c) Type B-2 waveform of the pulse-like signals in the AC band similar with a wave-packet. There is no coda phase, in contrast to seismic waves. A similar pattern was detected in the case of wetted granite specimens with a dominant frequency of 500 kHz (Yoshida *et al,* 1998). The S-P time was about 30 ms, suggesting an epicentral distance of 270 m. Several examples of events having P,S phases can be seen. The absence or very slight appearance of a P-phase indicates an epicentral distance larger than a few km.

(d) Type B-3 waveform in the AC band with a waveform compounded by type B-1 and type B-2.

(e) Type C waveform in the AC band. The waveform is the same as type B-2, but its amplitude is very large: 20–30 mV, with some 10 times larger than those of type A and B.

SSS02-04 会場:201B 時間:5 月 21 日 09:45-10:00

Physical properties of laboratory faults inferred from seismic event statistics during stick-slip experiments

Physical properties of laboratory faults inferred from seismic event statistics during stick-slip experiments

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Seismicity contains information about the in-situ faulting process from the plate boundary scale down to the scale of individual asperities. In this study, we consider the possibly smallest, seismically recordable earthquakes: those generated during stick-slip experiments, a laboratory analog to earthquakes. In the laboratory, seismic energy, radiated from brittle micro-cracking in form of acoustics emissions (AEs), has successfully been used to monitor the initiation and propagation of intact-rock failure. In contrast to much of the previous work, we concentrate on AEs that occur within or close to laboratory-created fault zones.

We present results from experiments on complex faults that were created by initial sample fracture. The fracture surfaces evolve due to successive stick-slips until they exhibit many of the hallmarks of upper crustal faults after the experiments. The structure of laboratory faults can be categorized into a gouge layer containing localized shear zones and a broader damage zone that marks the transition to the country rock. The transitional damage zone is generally associated with high AE activity that decreases as a power-law at larger fault-normal distances. The exponent of this power-law is connected to the roughness of the fault as revealed by saw-cut experiments with specific, pre-defined roughness.

We examined along-strike fault heterogeneity in X-ray computer tomography (CT) scans and spatial maps of AE statistics. We performed a detailed spatial analysis of event clusters before and after stick slip events, primarily focusing on b value, seismic moment release and AE event density. AE hypocenter distributions showed a high degree of spatial clustering close to low b value regions. Slip events and the connected acoustic emission 'aftershocks' nucleated within or at the periphery of areas of low b. To identify larger scale geometric asperities we combined fault structural information from post-experimental CT-scans with AE statistics. Asperities were connected to low b value regions, high moment release and areas of large AE event density gradients. The faults were anomalous thin in these areas.

Rough fracture surfaces during laboratory experiments, strongly favor the creation of spatial and temporal distinct AE clusters which have similar characteristics to seismicity observed on crustal scales. Specific seismicity anomalies may be an expression of fault heterogeneity and mark areas of larger seismic hazard.

キーワード: Earthquake Physics, Statistical Seismology, Laboratory Experiment, Seismic b-Value, Seismic Hazard
Keywords: Earthquake Physics, Statistical Seismology, Laboratory Experiment, Seismic b-Value, Seismic Hazard

SSS02-05 会場:201B 時間:5 月 21 日 10:00-10:15

非定常 ETAS モデルによる東北沖地震の誘発地震の解析
Analysis of Induced seismicity after the 2011 Tohoku-Oki earthquake by non-stationary ETAS models

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The epidemic-type aftershock sequence (ETAS) model is a stationary point process, and provides a good fit to an ordinary seismic activity. Its poor fitting suggests that the earthquake mechanisms are affected by changes in geophysical factors. Fault strength is one of the fundamental factors in a seismogenic zone, and its temporal change can induce nonstationary seismicity. Although changes in fault strength have been suggested to explain various phenomena, such as the remote triggering of seismicity, there has been almost no means of quantitatively monitoring this property in situ. For this purpose, we extend the ETAS model for non-stationary cases. This allows the parameters to be time-variant, which then describes anomalous features of the seismic activity. We prepare Bayesian models, and apply them to the data from inland seismic swarm activities that have been induced by the 2011 Tohoku-Oki earthquake of M9.0.

キーワード: ETAS モデル, 非定常モデル, ベイズ平滑化, 東北沖地震, 間隙流体圧
Keywords: ETAS model, non-stationary model, Bayesian smoothing, Tohoku-oki earthquake, pore fluid pressure

SSS02-06 会場:201B 時間:5 月 21 日 10:15-10:30

An earthquake forecast experiment in the northwest Pacific using RI model
An earthquake forecast experiment in the northwest Pacific using RI model

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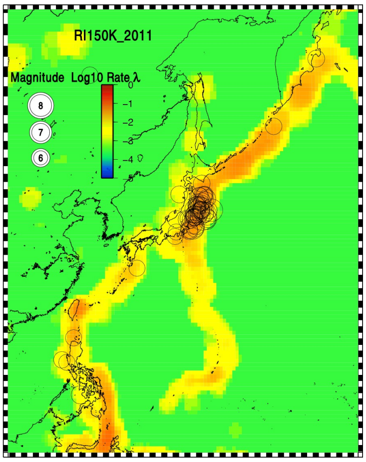
The Collaboratory for the Study of Earthquake Predictability (CSEP) has been conducting a prospective earthquake forecast experiment in the northwest Pacific from 2009. This test region includes 2011 Tohoku Earthquake, So, it is very important to evaluate testing results before and after this event. The northwest Pacific test region covers the longitude rand between 109.75 and 170.25 and then latitude range between -0.25 and 60.25. This region is gridded into cells of 0.5 °by 0.5 °and depth H <= 70.0 km is considered (Eberhard et al., GJI 2012). Forecast models define earthquake rates for each magnitude bin in magnitude range 6.0 <= M <= 9.0 (0.1 magnitude unit steps) at each node for consecutive 1-year time windows. The first forecast time stars at 1st JAN 2009. The GCMT catalogue was used for both model building and evaluation. CSEP testing centers (also CSEP-Japan) now use various tests to determine which models fit the observed data and which models forecast the distribution of seismicity best. For this study, we used the consistency tests of N, L, CL, S-tests developed by CSEP. For model comparison, we used the L-test 's log likelihood. For this study, relative intensity (RI) model was used to get earthquake forecasts. We evaluated the test results of smoothing radii of RI models of 50km, 75km, 100km, 150km, 200km, 300km, 400km, 500km and 1000km. We summarize the testing results as follows. (1) For 2009-2010 and 2010-2011 forecasts, All RI models passed all consistency tests. (2) For 2011-2012 forecasts, All RI models passed S and CL tests. (3) Uniform model didn 't pass S-test for all 3 rounds. (4) Comparing log likelihood, the RI model with the smoothing radii of 150 km showed the best performance of forecast in all 3 rounds.

キーワード: CSEP, NW-Pacific, forecast, GCMT catalogue
Keywords: CSEP, NW-Pacific, forecast, GCMT catalogue



SSS02-07 会場:201B 時間:5 月 21 日 10:30-10:45

地震検知の不完全性を考慮に入れた統計モデルの推定
Estimating statistical models of seismicity under incomplete detection of earthquakes

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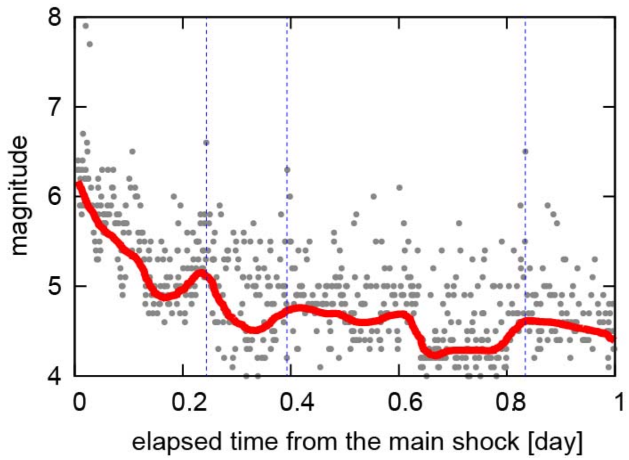
After a large earthquake, a vast number of aftershocks follow. The clustering property of earthquakes is commonly modeled by the Omori-Utsu formula of aftershock decay or Epidemic type aftershock sequence (ETAS) model. Usually, these statistical models have been directly fitted to the observed data above cut-off magnitudes enduring complete detection. On the other hand, it is well known that early aftershocks are substantially missed from seismic records because of overlaps of seismic waves caused by the main shock and congested aftershocks. In other words, earthquakes catalogues are highly incomplete during the early stages immediately after large earthquakes. Previous studies have applied the models to the datasets either avoiding the early part of the observed period of aftershock activity or taking a higher cut-off magnitude throughout whole period, so that such incompleteness of the data can be mitigated by an adjusted c-value of the Omori-Utsu formula or the ETAS. Nevertheless, such direct analysis of the catalogues may still produce some biased estimate. Also, we need to apply the ETAS model for a long period where the detection rates of earthquakes vary in time due to the development or reduction of seismic networks in and near focal seismogenic region.

Here we present a method for fitting the statistical models by considering the incompleteness of the catalogues. To do this, we developed a method to estimate non-stationary detection rate, based on the state-space model. This model can capture even irregular oscillation of the time-variation of the detection rate (Fig. 1). Then this model is combined with the Omori-Utsu formula of aftershock decay or the ETAS model.

Acknowledgement: This research is supported by the Aihara Project, the FIRST program from JSPS, initiated by CSTP.

Figure 1:Time-dependence of the magnitude of 50% detection rate (red line) for the observed afterhocks (closed circle) by PDE/NEIC, which occurred within one day from the 2011 Tohoku-Oki earthquake of M9.0 The estimate shows oscillating behaviour. The steep rise is accompanied with large aftershocks.



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実践的地震予測に向けた研究について
Research towards practical earthquake forecasting

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直接的に見えない地殻内部の断層やストレス、複雑で多様な地震発生のシナリオ、それに不明な要素の数々。依然として尽きないこれらを総合的に考えて未来を予測するには、確率予測が避けられない。大地震の予測の手掛かりになるのは各種の観測データの異常現象であろう。しかし、それが大地震の前兆なのか、どの程度切迫性があるのかなどの識別には大きな不確定さが伴う。一般に切望されているような決定論的地震予知は難しく、危険性を数量的に示す確率的予測が必要となる。予知につながりそうな定性的な知見が出ても、その定量的なモデリングが伴わないと困る。

地震予知の特効薬探しではなく、組織的に地震予測可能性を探る国際的共同研究（CSEP）が主要地震国で連携して進められている。これは地震活動の統計的モデルの開発を促し、確率予測の性能を評価することを当面の目標とする。それは、地震活動、地殻変動や電磁気変動などの様々な観測異常による各種の地震予測法の有意性と「確率利得」を評価できるインフラ（共通基盤）を整備することでもある。ここで確率利得とは「大地震の確率予測が相場の確率にくらべ何倍高くなるのか」という意味である。

CSEP は先ず、世界の各地域に適合した相場の地震活動モデルの成立と、それらの改訂を進めるのである。その際、予測の成績を測るものとして「尤度」が合理的なものと考えられている。もし有用な知見が組み込まれた新予測方式が出てくれれば、相場モデルと比較して、予測力が向上したか否かの評価ができる。

もとより、大地震を少しでも高い確率利得で予測するためには地震発生の仕組みや観測異常現象の包括的な研究が不可欠である。そもそも何かしらの異常が認められたとき、それが来るべき大地震の前兆であるか否かの識別は容易でない。しかし、黒白の判別は不可能としても、この異常の出現は、この範囲、この期間の大地震の発生確率を、相場のものと比べて、この程度まで増加させると言えるようになればよい。このように、異常現象の大地震発生への前兆性や切迫性の不確定性を見積もる必要があり、これには数多くの事例を地道に研究しなければならない。それらの知見をどの様に組み込んで、相場のモデルを超える確率予測を実現するのかが課題である。

実用的な確率地震予測のための研究の鍵は有意な異常現象を多数考慮して、各々の確率利得を高め、ベイズの公式から導かれる複合予測式を適用することである。これによると全確率の利得は近似的に個々の確率利得の積である。本講演では、宇津（1979）と安芸（1981 年）による重要な提案を再考し、より良い確率利得の定量化モデリングに向けた幾つかの例を提供したい。

さらに、数多くの解明された地震発生過程の研究に基づいて、多様な予測シナリオが考慮されなければならない。地震発生の多様性にうまく適応するためには、所定期間や地域固有のハイブリッドモデルを検討することが有用である。地震活動のための時空間モデルはデータの増加とともに、ますます複雑になってくるが、階層ベイズモデルを考慮することにより、様々なデータの地震活動に基づいて膨大な量の情報の多様性を反映した予測モデルを開発する必要がある。統計科学の方法が複雑な現象のシステムの予測に不可欠である。同様に、測地 GPS データの統計的なモデルの開発が必要である。統計地震学の発展が地球の複雑なシステムの研究のために不可欠であると信じている。また、複雑な現象の確率予測を理解する上で、市民を教育することも、統計科学に従事する研究者や実務家の義務である。

キーワード: 確率予測, 確率利得, 複合確率予測式, 点過程モデル, 時空間モデル, 階層ベイズモデル
Keywords: probability forecast, probability gains, multiple prediction formula, point process models, space-time models, hierarchical Bayesian models

Japan Geoscience Union Meeting 2013
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SSS02-09 会場:201B 時間:5 月 21 日 11:20-11:40

Testability of maximum magnitude estimates
Testability of maximum magnitude estimates

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Disasters caused by unexpectedly large earthquakes illustrate the need for reliable estimates of the maximum possible magnitude M (also known as M_{max}) at a given fault or in a particular zone. Such estimates are essential parameters in seismic hazard assessment, but their accuracy remains untested. In fact, whether M can be tested or not is still uncertain. In this study, we discuss the testability of M and the limitations that arise from testing such rare events. We use a simple extreme value theory approach to derive the sampling distribution for the maximum magnitude, i.e. the probability distribution for the maximum of a sample of earthquake magnitudes, and propose a straightforward hypothesis test for M. The test is based on the largest magnitude observed in the sample. If it is larger than the estimate of M, or it is too unlikely, given the assumed magnitude probability density function, the estimate of M is rejected. We then perform a sensitivity analysis to identify which parameters have the most influence on this sampling distribution and conduct a power analysis for the test. Our results suggest that the sampling distribution is relatively insensitive to the overall M, except when the b-value of the Gutenberg-Richter distribution is low and the size of the sample is high. Consequently, the power of the test is high only under optimal conditions, such as when the hypothesized value of M is grossly different than the true M, or when the seismicity rate is very high. Finally, we discuss that these limitations, in practice, may imply that a wrong maximum magnitude estimate can rarely be falsified, and express our concern about the use of these unfalsifiable estimates in seismic hazard assessment.

キーワード: Maximum Magnitude, Seismic Hazard, Seismic Risk, Statistical Seismology, Earthquake Forecasting
Keywords: Maximum Magnitude, Seismic Hazard, Seismic Risk, Statistical Seismology, Earthquake Forecasting

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日本の地震予知研究計画と統計地震学による地震発生予測実験
An earthquake forecast testing experiment with statistical seismology in Japanese earthquake prediction research program

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The current Japanese national earthquake prediction program, which inherits its essential observational network from all the previous programs, emphasizes the importance of modeling as well as monitoring for a sound scientific development of earthquake prediction research. Also, one major focus of the current program is to move toward creating testable earthquake forecast models. For this purpose, we joined the Collaboratory for the Study of Earthquake Predictability (CSEP) and installed, through an international collaboration, the CSEP Testing Centre, an infrastructure to encourage researchers to develop testable models for Japan and to conduct verifiable prospective tests of their model performance. In 2009 we started the 1st earthquake forecast testing experiment for the Japan area within the CSEP framework .

The experiment consists of 12 categories, with 4 testing classes with different time spans (1 day, 3 months, 1 year and 3 years) and 3 testing regions called All Japan, Mainland, and Kanto. A total of 203 models, as of November 2012, were submitted, and are currently under the CSEP official suite of tests for evaluating the performance of forecasts. I will give an idea how good results we will have. Also, we have conducted retrospective earthquake forecast experiments for aftershocks of the 2011 Tohoku-oki earthquake and 3-D seismicity in Kanto region. Our aim is to describe what has turned out to be the first occasion for setting up a research environment for rigorous earthquake forecasting in Japan.

キーワード: 地震予知, 発生予測, 統計地震学, CSEP
Keywords: Earthquake Prediction Reserah, Earthquake Forecast, Statistical seismology, CSEP

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Contribution of Coulomb stress changes by the 2011 Tohoku-oki earthquake on seismicity rate change in the Kanto region

Contribution of Coulomb stress changes by the 2011 Tohoku-oki earthquake on seismicity rate change in the Kanto region

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Abrupt changes in seismicity rate after the 2011 off the Pacific coast of Tohoku earthquake (MJMA 9.0) on March 11, 2011 are basically well explained by the static changes in the Coulomb Failure Function (dCFF) imparted by the gigantic thrusting. This suggests that changes in seismicity rate are sensitive for small changes of Coulomb stress (dCFF $<$ 1.0 bar), and accurate evaluation of Coulomb stress changes may improve the performance of earthquake forecasting after large earthquakes.

In the source region of gigantic event and its neighboring regions, the drastic changes in both hypocentral distributions and focal mechanism solutions were clearly observed. For example, in Tohoku region, focal mechanisms of earthquakes after the megathrust event are dominantly strike-slip type in the region where the thrust-type was dominant before the mainshock.

We examined a relationship between the dCFF due to the Tohoku earthquake and the seismicity rate change in Tokyo Metropolitan area following March 11. Because various types of earthquakes with different focal mechanisms occur in the Kanto region, the receiver faults for the calculation of dCFF were assumed to be two nodal planes of small earthquakes.

The computed dCFF shows positive values, which predicts seismicity rate increase, at intermediate depth in southwestern Ibaraki and northern Chiba prefectures and in shallow crust of the Izu-Oshima and Hakone regions. In these regions, the seismicity rate has actually increased since March 2011 with respect to the Epidemic Type Aftershock Sequence (ETAS) model, suggesting that the rate change was due to the stress increase by the Tohoku earthquake. The activated seismicity in the Izu and Hakone regions rapidly decayed following the Omori-Utsu formula, while the seismicity rate in the southwestern Ibaraki and northern Chiba prefectures is still increasing.

The observed temporal changes in focal mechanism distributions are well correlated with calculated dCFF. For example, thrust-type focal mechanisms (typical dCFF values ˜ +1-2 bars) relatively increased in an earthquake cluster in southwestern Ibaraki after March 11, whereas normal-fault type earthquakes (typical dCFF values ˜ -0.5 bars) relatively decreased compared to before March 11. The dCFF values calculated for focal mechanisms of the earthquakes after March 11 show more positive values than those before March 2011, supporting a hypothesis that the 2011 Tohoku earthquake triggered the seismicity changes in the Kanto region, whereas some other possible factors (e.g., dynamic stress changes, excess of fluid dehydration, post-seismic slip, large aftershocks, or viscosity) may also contribute the rate changes.

キーワード: seismicity rate change, Kanto region, Coulomb stress change, focal mechanism
Keywords: seismicity rate change, Kanto region, Coulomb stress change, focal mechanism

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東北地方太平洋沖地震による首都直下地震ハザードへの影響
Impact of the 2011 M=9.0 Tohoku-oki earthquake on increased seismic hazard for greater Tokyo

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The Kanto seismic corridor surrounding Tokyo has hosted 4-5 damaging M>=7 earthquakes in the past 400 years, and 55 M>=3 shocks per year were recorded in the decade before the Tohoku-oki earthquake. Both observations would indicate a 1.0-1.4% annual M>=7 probability, or 5-7% for 5 yr. Immediately after the Tohoku-oki earthquake, the seismicity rate in the corridor jumped ten-fold, while normal and strike-slip focal mechanisms all but ceased. The seismicity rate then decayed for less than a year, after which the rate steadied at three times the pre-Tohoku rate. The seismicity rate jump and decay to a new rate, as well as the shutdown of non-thrust mechanisms, can be explained by static Coulomb stress imparted to faults 40-80 km beneath the Kanto plain by the Tohoku rupture and postseismic megathrust creep. We fit the observations with a rate/state model, which we use to estimate the time-dependent probability of future large earthquakes in the corridor. Although it is possible that the increased Kanto seismicity accompanies accelerated creep that is shedding -rather than accumulating- the stress imparted by Tohoku-oki, the ratio of small to large shocks was not changed by the Tohoku-oki mainshock, and so the simplest assumption is that the probability of large shocks has climbed with the increased rate of small ones. Thus, for a b-value of 0.9, we estimate a 17% probability of a M>=7.0 shock over the 5-year prospective period, 11 March 2013 to 10 March 2018, two-and-a-half times the probability before the Tohuku-oki earthquake.

キーワード: 東北地方太平洋沖地震, 地震活動, クーロン応力変化, 地震ハザード, 地震発生確率
Keywords: Tohoku-oki earthquake, seismicity, Coulomb stress change, seismic hazard, earthquake probability

SSS02-13 会場:201B 時間:5 月 21 日 12:25-12:40

M=9.0 Tohoku Earthquake and tsunami; a new interpretation

M=9.0 Tohoku Earthquake and tsunami; a new interpretation

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M=9.0 Earthquake

A M=9.0 earthquake occurred on March 11, 2011, with its unusually large magnitude drawing our attention. Here, I propose a process different from that of the Benioff-plane origin, one that involves a spray-fault that periodically destroys the fore-arc region. This process involves tectonic erosion, which includes the collapse of the hanging wall of the overriding lithosphere, as well as transport of the collapsed materials into the deep mantle, presumably as far as the mantle transition zone, a process that contributes to the formation of the 2nd Continents through time.

The origin of spray faults is a manifestation of the physically unstable triangular region between the material boundary (trench) and the physical boundary (spray fault). The tightly connected Benioff thrust dragged down the frontal part of overriding plate to reactivate the spray fault, triggering the M=9.0 earthquake.

Tsunami

The spray fault occurs right below the trench-slope break which is a turning point of slope change from the shallow to the deep trench inner wall. Right above the fault, a sedimentary basin is present. Spray faulting resulted in a huge-scale submarine landslide, which led to the collapse of a huge volume of basin sediments, triggering the tsunami off Sendai.

The river drainage system on Northeast Japan is remarkably different from Southwest Japan. Two major rivers, one from the north and the other from the south, transport eroded sediments into the ocean, which contribute to the formation of the sedimentary basin off Sendai. This basin periodically collapses, approximately every 1000 years, causing the ruinous tsunami.